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Design of a system for management and monitoring of vehicles transporting solid waste in open-cast coal mines

Thiết kế hệ thống quản lý giám sát các phương tiện vận chuyển chất thải rắn trên mỏ than lộ thiên

Research article

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Today, solid waste management in coal mines is an urgent requirement for the coal mining industry. The overlying materials removed from a seam of coal are solid wastes transported to dumping sites and should be strictly, efficiently managed and monitored by an automatic system. These wastes must be separated for use as leveling and filling materials or residue materials need to be processed in order to minimize the impact on the environment. The system was designed to manage and monitor vehicles transporting solid waste in open coal mines to force them in tasks of taking solid wastes and giving out these wastes in the right places, to help collect and process suitably. The results showed that the calculation of numbers of trips using the software program named "Management of trucks" achieved the statistics of running trucks between the points of removing wastes and dumping sites, in which the numbers of valid and invalid trips were given out. The monitoring process obtained the statistics of active and inactive total time of vehicles transporting solid waste. From that we can calculate and classify them at each dumping site. In addition, the statistics of productivity of power-shovels, fuel consumption levels of excavators and trucks were also gained.

Hiện nay quản lý chất thải rắn tại các mỏ than là một yêu cầu cấp bách đối với ngành khai thác than. Các chất thải khi bóc vỉa được chở đến các bãi đổ cần có một hệ thống quản lý giám sát chặt chẽ. Những chất thải này phải được phân loại để làm vật liệu san lấp hoặc vật liệu cần xử lý nhằm giảm thiểu các tác động tới môi trường. Hệ thống được thiết kế có nhiệm vụ quản lý và giám sát các xe chở chất thải trong quá trình khai thác tại các mỏ lộ thiên, đảm bảo các phương tiện này được xúc và đổ đúng nơi quy định, giúp thu gom, xử lý một cách phù hợp. Kết quả cho thấy rằng việc tính toán số lượng các chuyến xe bằng cách sử dụng chương trình phần mềm có tên là "Quản lý xe tải" thu được các số liệu thống kê xe chạy giữa các điểm xúc chất thải và các điểm đổ, trong đó thống kê được số lượng các chuyến đi hợp lệ và không hợp lệ. Quá trình giám sát thu được các số liệu thống kê của tổng thời gian hoạt động và không hoạt động của các phương tiện vận chuyển chất thải rắn. Từ đó chúng tôi có thể tính toán và phân loại chúng ở mỗi điểm đổ chất thải. Ngoài ra, cũng thu được các số liệu thống kê năng suất hoạt động của máy xúc, mức tiêu thụ nhiên liệu của máy xúc và xe tải.

Keywords: management and monitoring, solid waste, open coal mines, GIS

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1. Introduction

The coal mines in Vietnam are divided into two categories: open-cast coal mines and underground coal mines. There are five open-cast coal mines in operation belonging to Vietnam National Coal Mineral Industries Group (TKV). They are Deo Nai, Ha Tu, Nui Beo, Cao Son, Coc Sau in the region of Cam Pha, Quang Ninh. Coal mining operations often make a large amount of solid wastes. After the survey on processing of coal mining activities in Ha Tu and Deo Nai, the authors provided a management solution of the solid wastes including soil, rock block, rubble and other wastes arising from removing surface materials of coal seam and exploitation.

In the past, the monitoring process was done by manual labour. Because of having outdated devices and limited staff for management, the drivers of vehicles transporting solid wastes did not give out these wastes in the right place. They tended to unload the wastes at nearer places in order to improve number of transported trips and to save fuel level from each trip.

The cause of this problem originates in consciousness of drivers and characteristics of working conditions in open-cast coal mines. The topology of coal mines is very complex. Locations of waste dumping sites change frequently. In addition, vehicles must move in a very wide area, so their monitoring and management by other workers is a complex problem.

Because of above mentioned difficulties, an urgently needed solution is to have an automatic system to manage and monitor vehicles transporting solid waste in open-cast coal mines. This system will count the number of trips of vehicles moving back and forth, verify whether the truck runs in right routines. It can give out statistics of productivity of each vehicle and/or excavator, also of the productivity of all vehicles and excavators of the company periodically. This helps reduce the subjective impact of humans in the process of management. From that we will manage closely and avoid negative problems in the implementation. It also helps to manage solid waste in mining, avoids the situation of giving out the waste to wrong places, so the waste is collected, planned and properly dealt with.

2. Study place and actual state

2.1. Survey of location

The topography of the open-cast coal mine is a complex mountainous terrain. Through a survey in Ha Tu Coal mine, we obtained the complicated trajectory of the moving vehicle, as shown in Figure 1, from bottom level of exploited place (-180m) up to the summit (300m +).

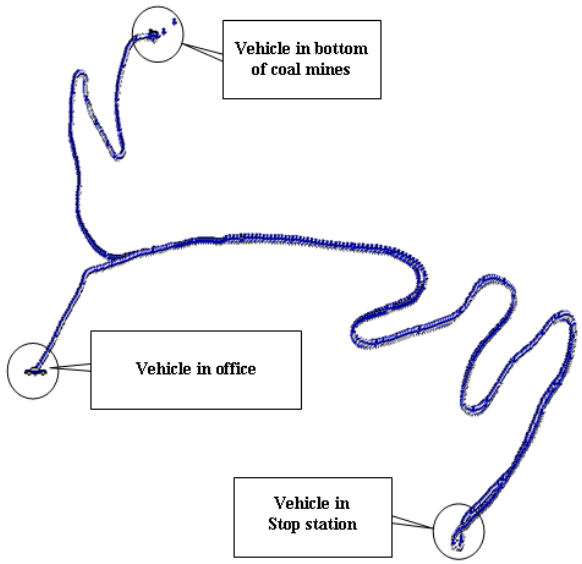

Figure 1: Trajectory survey in Ha Tu coal mine

2.2. Method of management

The manual management process of vehicles transporting solid waste consists of following works:

- Daily, management divisions determine locations of removing solid waste and places of giving out solid waste on the map, use their experiences to outline trajectories and estimate the length of distance as well as the level of fuel for each of vehicles.
- Each vehicle receives before its shift a command to transport waste following identified trajectories.
- Arrival and leaving time at the waste dumping place is recorded by the management staff on book to certificate the trip.
- When the vehicle comes to the dumping site, different staff counts and confirms the trip.
- The number of trips is counted by management staff, and then combined with the length of trajectories and fuel level to calculate economic efficiency as required.

The supervision of the trucks on open-cast coal mine ensures that the trucks work three shifts throughout the day, with the first shift change being from 7h15 to 8h00, the second from 15h30 to 16h00 and the third from 23h15 to 24h00.

The automatic management system has been designed to solve complex situations of manual management method. Further, it helps reduce the number of labors, increase accuracy, improve labor productivity and avoid of indiscriminate dumping waste.

3. Design of management and monitoring system

3.1. Structure of system

The system architecture consists of receiving-transmitting equipment on vehicles and receiving equipment at the

station. It is structured according to the following diagram (Le et al., 2010):

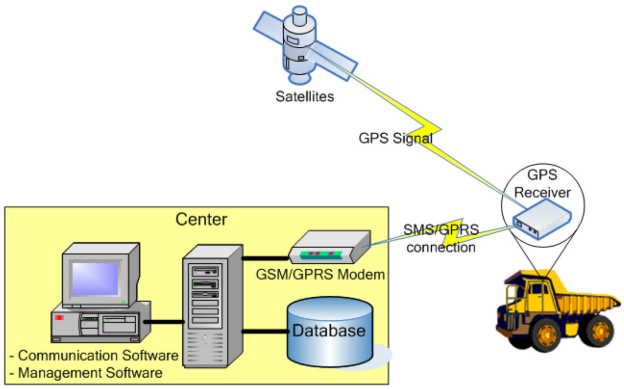

Figure 2. Structure of Management and Monitoring system of vehicle transporting solid waste in open coal mines

The data in $GPMRC form of GPS signal are received by the device on the vehicle. These data were programmed to calculate time, speed, longitude and latitude. These results, together with the vehicle's code are transmitted to the station by GSM network. GSM/GPRS modem in the station receives that data and transmits it to the computer to display the position of that vehicle on map.

The management program at the station receives information about that vehicle and gives it to the data base. From that, it calculates the amount of transported solid waste to each dump. Through the volume of this waste, the management staff of the trucks will adjust the trajectory, and the suitable amount of waste type transported by the later trucks.

3.2. Device on vehicle

The receiving-transmitting device on vehicles contains two channels used for exchanging data between the device on the vehicle and the management system. The first channel using GPRS service allows exchanging large data with high speed. It is suitable for applications requiring continuously and intermediately updating positions, like online navigation function. The second channel uses SMS service. One SMS message only includes a maximum of 160 characters and its delay time is quite long. So, that service is used to switch GPRS when the device moves in an area losing GPRS signal. This channel is also used for management applications that don't need to update fast.

The device on the vehicle includes microcontroller PIC 24F64GB106; module SIM 548 using for receiving GPS signal and transmitting GSM/GPRS signal; pulse isolation power supply; memory card and some supplemental devices, such as led, horn. Input power supply for this device is from 12VDC to 24 VDC. Output supply includes 5.0 VDC and 3.3 VDC.

The software program is built on Microchip's MPLAB development system for Microchip C30 compiler Toolsuite.

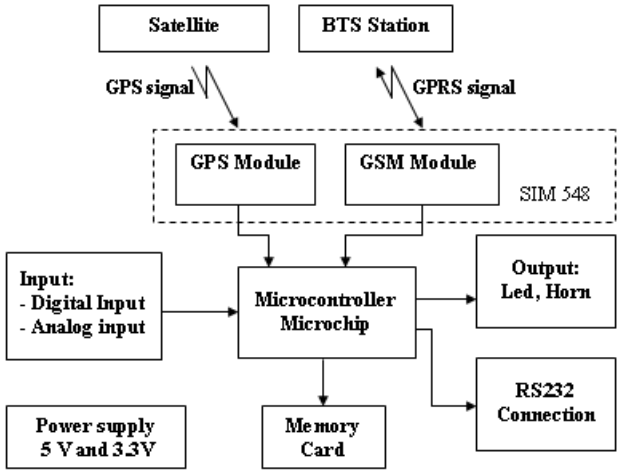

Figure 3. Block diagram of vehicle device

Figure 4. Mounting device on vehicle

3.3. Devices in station

There are devices in the station such as a receiving device, a PC and also a SMS gateway and CPUs, using for database sever and websever. Other computers can be connected to the system by internet connection.

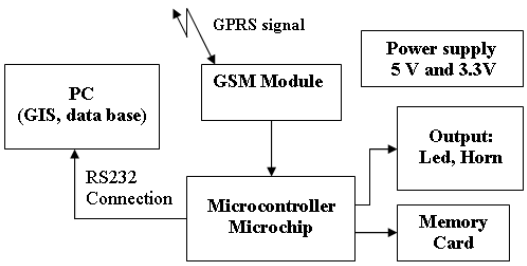

Figure 5. Block diagram of receiving device

GIS software provides the functions and tools needed to store, analyze, and display geographic information. The main components of GIS software are:

- Tools for loading and processing geographic information
- Database Management System (DBMS)
- Inquiry support tools for analyzing and displaying geographic information.
- The graphical user interface (GUI) for easy access to tools

Figure 6. Device in Station

The database server, in general, is a data storage system. Data stored in the database include: location data received from GPS device, data for device management and for user's information management configuration parameters for system operation mode, geographic information database. Web Server is a web application integrated GIS technology (WebGIS). This is where some processes take place, such as collecting and analyzing requirements from users, data processing, ensuring information security, management of interaction process between users and GIS systems over the internet. When working, Web Server needs to access data in the Database Server and interact with GPS device. Web application is designed in Client / Server model.

The software for monitoring system managing solid waste is designed by two methods: offline (retrieving data from the file on the device mounted on vehicles), and online (directly transmitting data to station). The offline system consists of two main components that are relatively independent of each other. These are equipments mounted on the vehicle and software installed in the center. The device mounted on a vehicle is responsible for continuously receiving signals from the satellite, calculating to determine longitude, latitude and altitude at the current location, then writing this information on the storage device.

Software installed in the center allows the connection with the device mounted on the vehicle to read the data recorded during the trajectory. These data are used to calculate velocity of the truck and display the points on the digital map that the truck went through. When connecting these points together, we obtain the trajectory of the truck on the map.

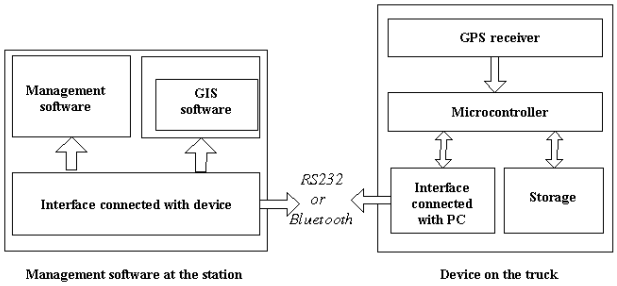

Figure 7. Block diagram of offline system

The online system consists of three main components: equipment mounted on the vehicle, management software at the center, mobile communication network connecting the trucks and the center.

In traffic management, online system is particularly suitable for systems in which operation of vehicles are often subject to the control center, for example, management system of bus and taxis in the city. In those systems, knowing the location of the vehicles is one of the important factors that help the staff make decisions rationally.

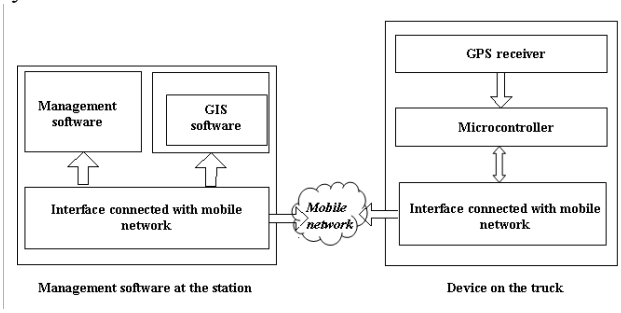

Figure 8. Block diagram of online system

The stations of the management and supervision system are operated by the transport firm members of the company. Each station is responsible for managing some specific routes. Facilities serving for management include (Dang, 2008):

LAN: Ethernet 10/100BASE-T. It is used to connect a computer in the control station.

WAN equipment: Connecting to the control center, the network can use existing network in the company.

Software: Software at the station includes the following Tools:

- Software for management and supporting decision-making on the basis of TraffMan technology. It is built based on the Client / Server model to display the vehicle location on a digital map. Information between the vehicle and the control station is exchanged by using SMS or GPRS. The operators work with software through the Client installed at the PC. The Server is installed in a host computer in the network. The Client provides a graphical user interface (GUI) allowing the users to load and process data of the program, showing the location of the vehicles on a digital map and sending operation commands or helping information to the driver. The Server provides services for database connectivity, connected to the device on truck through software SMS Control or GPRS component.
- Database Management System MS SQL Server 2000: Storage information collected from truck.
- Software for receiving/sending SMS (Zyneo SMS Control): Allowing sending and receiving SMS by a PC through a GSM modem connected to computer via the RS232 port.
- Data Communication Software GPRS (GPRS Component): Through a GSM modem, this software creates UDP connection from a PC to a mobile device.

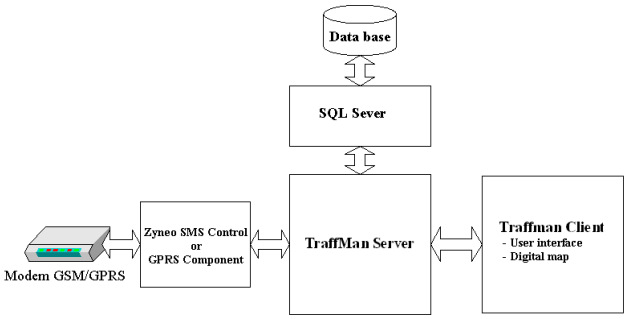

Figure 9. Management software at the station

The digital map shows trajectories on Mapinfo MapX by the program "Management of coal trucks" as follows:

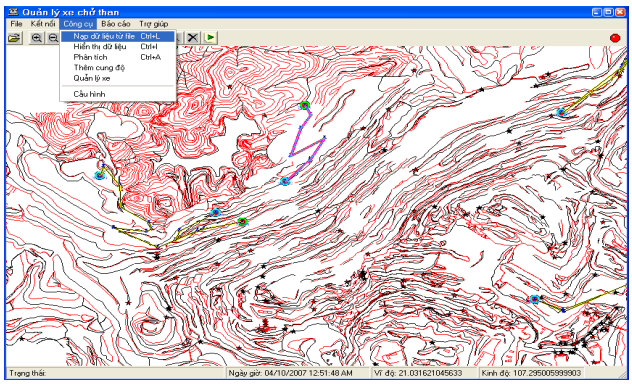

Figure 10. Monitoring of vehicle on MapX.

This management and monitoring system used for open-cast coal mines was checked, tested, and put into application. The obtained results were significant and met the following technical requirements:

- Allowing management of online media with delay time is 12 seconds.
- The number of managed vehicles is not limited.
- The trucks are not required to go back to station to transfer data. It is convenient to operate directly the drivers.
- The output data are given in data analysis software to calculate number of trips and check valid trips.

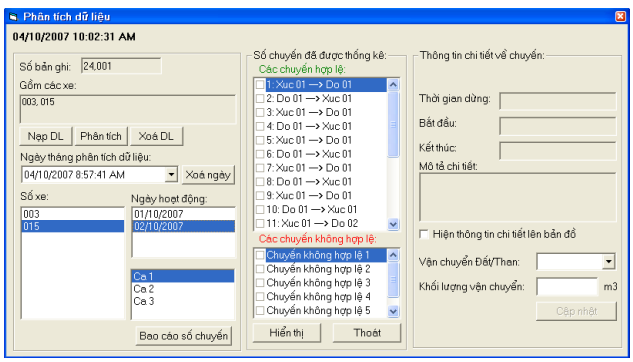

Figure 11. Result of data processing

The calculation of the number of trips using the software named "Management of trucks" achieved the necessary requirements:

- Statistics of running trucks between the points of removing waste and dumping sites, in which numbers of valid and invalid trips were given out
- Statistics of active and inactive total time of vehicles transporting solid waste. From that we calculate and classify them in each dumping site as well as whole dumping sites.
- Statistics of productivity of excavators
- Calculation of level fuel for each truck and excavator as well as whole fuel consumption.
- Statistics of productivity of workshops and of the company

4. Conclusion

The created automatic system solved the problem of manual management. It also helps improve accuracy, process a large amount of data and eliminate the gaps in management process.

By verifying if a truck carrying solid waste runs in right routine or not, we can count the number of trips that a vehicle runs in a work shift as well as the total trips of entire groups of vehicles. The system will provide exact data about the amount of dumped wastes and waste areas need to be treated. In addition, the system also helps obtain statistic data about productivity of each excavator and the periodic data about productivity of the whole company. Therewith, the role of subjective decisions of humans in the management process is being reduced, allowing to manage more precisely the implementation process.

The amount of solid waste placed in the defined sites will help conveniently manage and treat solid wastes in Ha Tu coal mine, Quang Ninh province, avoiding environment pollution.

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